

# IJAER

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## Damage Diagnosis Induction Motor Based on Fuzzy Logic

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### Abstract

There is a prototype of an intelligent software made based on fuzzy logic that can diagnose damage/fault of 1 phase induction motor caused by sound (noise), speed, current, voltage and unstable temperature.

The findings of this research revealed that: (1) the intelligent software made had worked properly as expected by the industry companies (PT. Semen Tonasa, PT. IKI, CV. General Electric Workshop, Lab. of UPTD BPPT South Sulawesi Province, Lab. of Electrical Engineering Department and Computer of Faculty of Engineering UNM), which was to describe the types of faults suffered by 1 phase induction motor so that it could be quickly resolved, (2) the diagnostic system tested in the industry had successfully detected types of faults suffered by 1 phase induction motor against the effect of current, voltage, speed, noise and unstable temperature. It was described by the inference technique with fuzzy input applied of which the result described that the primary coil insulation already paled, the bearing of the machine was still normal, the additional coils had been burned, and the condition of the capacitors already melted, (3) the intelligent software made could detect 55 and 3125 types of faults, (4) the software made was flexible which means that new input can be added to the facility related to causes of damages/faults suffered by induction machine.

**Keywords:** Intelligent Software, Fault Diagnosis, Inference Technique, Current, Voltage, Speed, Sound, and Unstable Temperature.

### INTRODUCTION

The needs of today's modern society, especially in the world of industry face a lot of very rapid development. Industry is a very important means that meets human needs. Industry in the developed countries and the developing countries, generally use induction motors as propulsion systems in supporting the continuity and the quality of the production. This electric motor has many advantages compared to other propulsion systems due to simple construction, using no fuel and no noise.

Motor is an electromechanical device that works by changing the electronic pulses into discrete mechanical movements. The motor moves based on a sequence of pulses given to the

motor. Therefore, to drive the motor, motor control is needed to generate periodic pulses. The electric motor is the same as human life that has an active productive period of time in which negligence will lead to the motor that does not function in accordance with prescribed standards or does not function according to its usefulness. Hence, there is a need for diagnostic in the motor equipment which does not work properly.

Method of diagnosis is necessary to determine whether or not the electric motor is normal. Diagnosis performed by the ability of the human memory is sometimes setback caused by the age factor so that measurement accuracy becomes less precise and the decision-making level gets low. Given adequate facilities and a fairly high degree of accuracy in the decision-making, then it is most needed to help humans, it can be implemented by using computer as a tool to diagnose every problem that appears.

The results of the diagnosis can quickly describe which components suffer negligence so that decision to determine what parts of the motor are damaged can be made quickly and appropriate action can be taken to repair them based on the instructions that have been described.

### RESEARCH PROBLEMS

In general, the issue examined in this research is how to make a software that can diagnose multi damage/fault (caused by voltage, current, speed, sound and unstable temperature) that occur in the induction motor. Phase based on the principles of fuzzy logic. Thus, the problems of this research are:

1. How to create an intelligent software that can diagnose multi damage/fault of 1 phase induction motor based on the principles of fuzzy logic.
2. How is the description of the micro controller-based diagnostic system for diagnosing an induction motor against the effects of voltage, current, speed, sound and unstable temperature (multi damages/faults).
3. How is the description of the benefit of the intelligent software after enabled on PT. Industri Kapal Indonesia (PT. IKI), PT. Semen Tonasa, CV General Electric Workshop (Dynamo Workshop), laboratory of UPTD BPPT South Sulawesi Province, and laboratory of the Electrical Machine, Faculty of

Engineering, Universitas Negeri Makassar.

## OBJECTIVES OF THE RESEARCH

This research aims to (1) create an intelligent software that can diagnose multi damage/fault of 1 phase induction motor based on the principles of fuzzy logic, (2) provide a description of the micro controller-based diagnostic system for diagnosing an induction motor against the effects of voltage, current, speed, sound and unstable temperature (multi damages/faults), (3) provide a description of the benefits of the intelligent software after enabled in PT. Industri Kapal Indonesia (PT. IKI), PT. Semen Tonasa, CV General Electric Workshop (Dynamo Workshop), laboratory of UPTD BPPT South Sulawesi Province, and laboratory of the Electrical Machine, Faculty of Engineering, Universitas Negeri Makassar.

## REVIEW OF RELATED LITERATURE AND CONCEPTUAL FRAMEWORK

### The Principles of 1 Phase Induction Motor

1 phase induction motor is an electric power tool that serves to convert electrical energy to mechanical energy with the principle of electromagnetic induction.

Magnetic flux on a 1 phase induction motor changes direction which causes motor difficult to execute (start). To enlarge the spinning power of the motor when run, the assistance of the auxiliary coil principle forming new magnetic fields which has different phase from the main magnetic field is needed. In this case, there must be new electrical flow which is not in the same phase with the electric current flowing in the primary coil (main winding). Thus there should be a second coil separated from the main coils which are often called assisting coils.

It is in fact that the 1 phase motors use 1 phase electricity but in the stator winding there are two-phase electric current flowing to the primary coil and the auxiliary coil.

In the 1 phase induction motors, rotary field does not occur directly, as it is to obtain the necessary rotary field windings which are placed between the main winding. The function of the auxiliary winding is to petrify the process of the rotary field in the motor stator. To get the rotary field, the auxiliary winding is modified so that the phase shifts as much as 90° of electricity.

The capacitors mounted on the auxiliary coils will shift the phase of the currents in the windings, in which current that flows in the auxiliary winding leads 90° electricity to the flow in the primary winding.

The phase shift makes the direction of the exchange field on the phase of the auxiliary winding and primary winding different. This difference cause rotary field in the stator.

At the motor running capacitor, capacitor and additional coil

are not taken off after the motor starts, the construction can be simplified by providing current connection and there is an improvement in power factor, efficiency and moment pulse formation. Capacitor and the additional coil can be designed to work perfectly in two phases to any desired load. Thus the backward field will be lost, which causes improvements in terms of efficiency. Besides, the moment pulse formation will disappear, a double stator frequency, in which the capacitor will be valid as an energy storage to smooth the formation of a pulse at the input of the power in the single phase grid.

The motor current is not obtained from certain sources, but the currents which are induced due to the relative difference between the rotation of the motor with a rotary field (rotating magnetic field) generated by the stator currents. Stator windings connected to a voltage source will produce a magnetic field that rotates at synchronous speed ( $N_s = 120F / p$ ). This diagnosis of induction motors uses two poles with a frequency that is set for the Indonesian territory of 50Hz, so the stator rotational speed is 3000 rpm. Rotary field in the stator will cut the conductors in the rotor so that it is induced with currents and in accordance with the Lenz law, the rotor spins following the rotor rotary field. The speed difference between the rotor ( $n_r$ ) and stator ( $n_s$ ) is called slip. Induction voltage in the rotor of the induction motors depends on the relative speed of the rotor to the rotary field, when the rotor speed equals to the speed of the play field, then the rotor wire is not induced with voltage. This will cause the absence of current and magnet field in the rotor so that no induction torque is generated and the motor will slow down or does not rotate. In other words, in order to keep induction motor spinning, there must be a difference between the speed of the rotor and rotary field of the stator, this difference is called speed slip

$$n_{slip} = n_s - n_r \dots\dots (1)$$

Where :

$N_{slip}$  = slip speed of the machine

$N_s$  = speed of the rotary field

$N_r$  = speed of the rotor

### Substitute Circuit of Motor Induction

An induction motor has a close method and the principle of utilization of symptoms and physical phenomena with a voltage transformer and electric current. The closeness of the induction motor with the transformer is caused by the idea of its design development which follows the behavior and properties of a transformer (electricity voltage). Model and substitute circuit of induction motors are almost the same as the model of a transformer (Soe, NN, et al .. (2008) (15) as shown in Figure 4.1

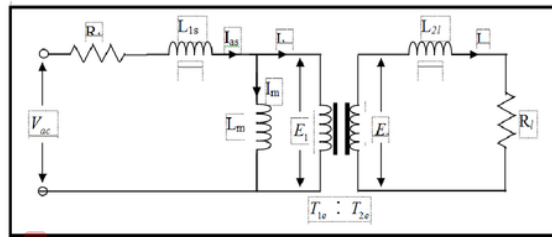


Figure 1: Basic Model of Induction Motor Substitute[15]

The mathematical model can be used to develop insight and knowledge of the induction motor in order to better understand and explore in detail its nature and characteristics. Although it is very difficult to calculate all parameters of induction motor properly, it is a must to determine the value of the parameters through the estimation when being analyzed.

Substitute circuit can be well modified to observe and take into account damages in the core, friction, and damages of the anchor when the motor is being operated<sup>(8)</sup>. Stable operating characteristics (steady state) of an induction motor is often observed and investigated using substitute circuit (1.6.8) as illustrated in Figure 4. 2

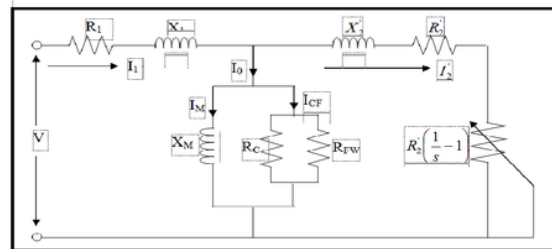


Figure 2: Substitute Circuit of an Induction Motor[1,6,8]

At this substitute circuit there are R1 and X1 each of which

plays as resistance and reactance of the stator winding. Meanwhile, R2 and X2 describes resistance and reactance of the relative rotor to the stator. The rest are the core leakage losses shown by resistance Rc, and magnetization reactance shown by Xm. Difference of the relative rotational speed between the rotor and stator or slip is indicated by the variable s. Slip of an induction motor is described by the formula (Rijanto, E, and Santoso, A. (2009)[13] below:

$$s = \frac{\omega_{sm} - \omega_{rm}}{\omega_{sm}} = \frac{\omega_e - \omega_r}{\omega_e} \quad (2.1)$$

The substitute circuit can be used as a calculating facility for various quantities of operations like stator current, input power, damages, induction torque, and efficiency. The aspect of power required in the operation, parallel resistance (shunt) RC can be ignored, while the core damages can be incorporated into efficiency calculations in conjunction with friction, winding, and other damages.

Therefore, the accuracy of estimating the damages/faults suffered by an induction motor in operation will be a very important in addition to the error happened when estimating efficiency [5]. Core damages depend on the applied voltage, while the friction damages and anchor damages depend on the operating speed of the motor. When the motor is not loaded, the input power is only used to calculate the no-load damages in the form of copper damage of the stator core, core damages, anchor damages, and friction damages<sup>(7)</sup>. Substitute circuit parameters in Figure 4.2 above can be obtained from the dc voltage test, no-load test and locked-rotor test- "blocked" (Ayasun, S., and Nwankpa, CO (2005) [1], Soe, NN, et al., (2008)) [15].

### System Components of Fuzzy Expert

A system is known as a system expert if it has certain traits and characteristics. It should also be supported by components of an expert system that is able to describe those features and characteristics. Components of the fuzzy expert system can be described as follows:

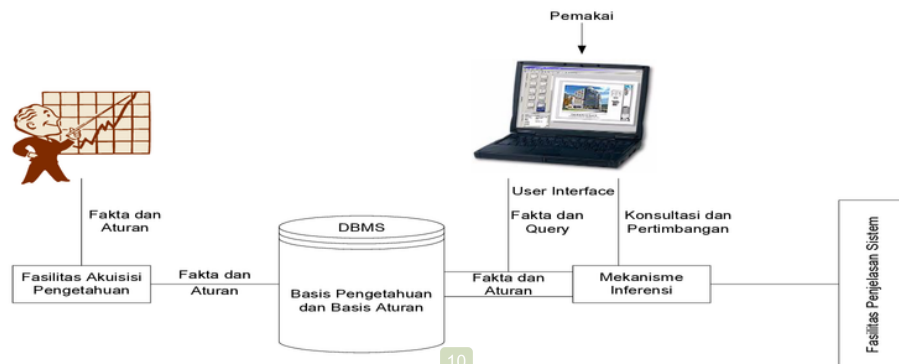


Figure 3: Chart Structure of the Fuzzy Expert System



Five essential components in the picture is the acquisition of the knowledge base and the rule base, inference mechanism, facility of a program description and a user interface that is a unity which cannot be separated. Meanwhile, self-learning facility is a component that supports fuzzy expert system as an advanced artificial intelligence.

#### Explanation of the Chart Structure

There are three essential elements of the development of the fuzzy expert systems users, and system.

##### a) Knowledge Acquisition Facility

This facility is a process to collect data of the problem from the expert system. Knowledge can be gained in several ways such as books, science journals, experts in their fields, reports, literature, and so on.

Sources of knowledge mentioned above will serve as the documentation to be studied, processed and structurally organized become knowledge base.

##### b) Knowledge Base and the Rule Base

Once the process of knowledge acquisition is completed, then this knowledge must be represented into the knowledge base and rule base which are subsequently collected, coded, organized and described in certain form of design into a systematic form. There are several ways to represent the data into the knowledge base as proposed by Barr and Feigenbaum in 1981, namely, data in the form of attributes, rules, semantic networks, frames and logic. All forms of data representation is intended to simplify the data so it is easy to understand and make the process of program development effective.

##### c) Inference Mechanism

Inference mechanism is part of a system expert melakukan reasoning by using the contents of a list of rules based on the rules specified data patterns. During the consultation process between the system and the user, the inference mechanism to test the rules one by one until the condition of the rule is true.

#### Fuzzy Inference System

Fuzzy Inference System (FIS) is a computational framework that is based on the set theory of fuzzy, the form of fuzzy rules IF-THEN and Fuzzy reasoning. In general, figure 2.7 below is a block diagram of a fuzzy inference process.

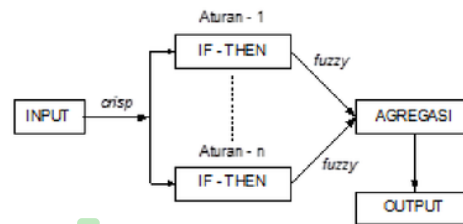


Figure 4: Block Diagram of the Fuzzy Inference System

Fuzzy inference system receives crisp input. This input is then sent to the knowledge base consisting n fuzzy rules in the form of IF-THEN. Fire strength will be sought on any rules. Next, the aggregation will be done from all the rules. Furthermore, the aggregation results will be diagnosis process output.

#### Fuzzy Logic

##### Fuzzy Set :

Fuzzy set is a class of objects with a continuous degree of membership. A fuzzy set is characterized by its membership function which is displayed as an object on a range of values between zero and one. Thus the fuzzy set can be defined mathematically. Definition shows a value that represents the degree of membership of each individual in the universe of discourse.

Fuzzy set is written as a sequential pair in which the first element indicates the name of the element and the second element indicates the value of membership. Suppose a fuzzy set for  $\bar{A}$  = High, described as follows:

$$\mu_{\bar{A}}(x) = \begin{cases} 0 & ; 220 \leq x < 275 \\ \frac{x-220}{275-220} & ; 220 \leq x \leq 275 \\ \frac{330-x}{330-275} & ; 275 \leq x \leq 330 \end{cases}$$

##### Membership Function:

Membership function (MF) is a curve showing the mapping of the point of data input into its membership values.

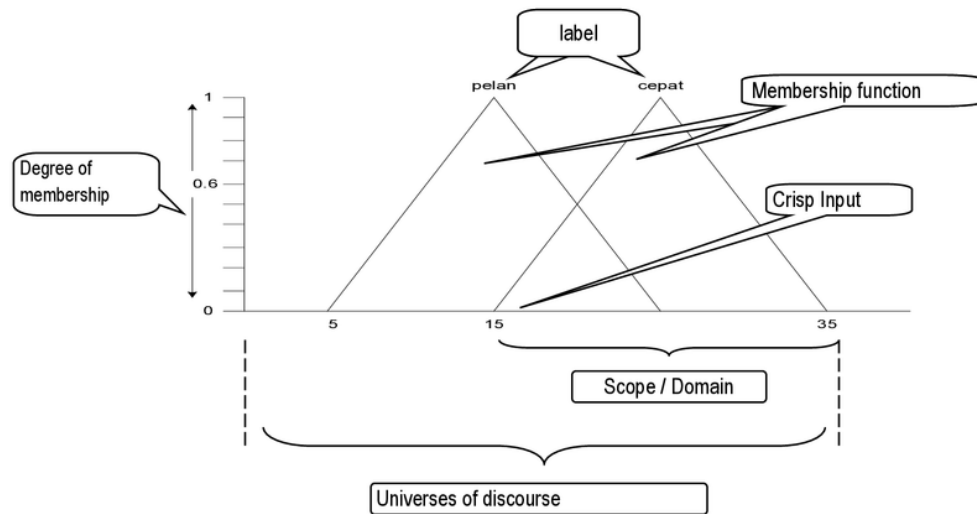


Figure 5: Flowchart of the Research.

There are three processes in the fuzzy system, namely:

1. Fuzzification
2. Rule Evaluation
3. Defuzzification

#### Related Studies

Induction motor testing at the laboratory scale in the form of hardware and software facilities with MATLAB for educational purposes is well presented in an article by Ayasun, S., and Nwankpa, C. O (2005) [1]. Detection effort, test and operation failure diagnosis and the measurement scale that affects the performance of the induction motor can be seen in the articles by Faiz, J et al. (2006) 2004) [2,3]. Gosbell, V.J., et al. 92 002) [4] published a technical report about the imbalance of the 3 phase power supply from electric power quality study center Univ. of Wollongong Australia.

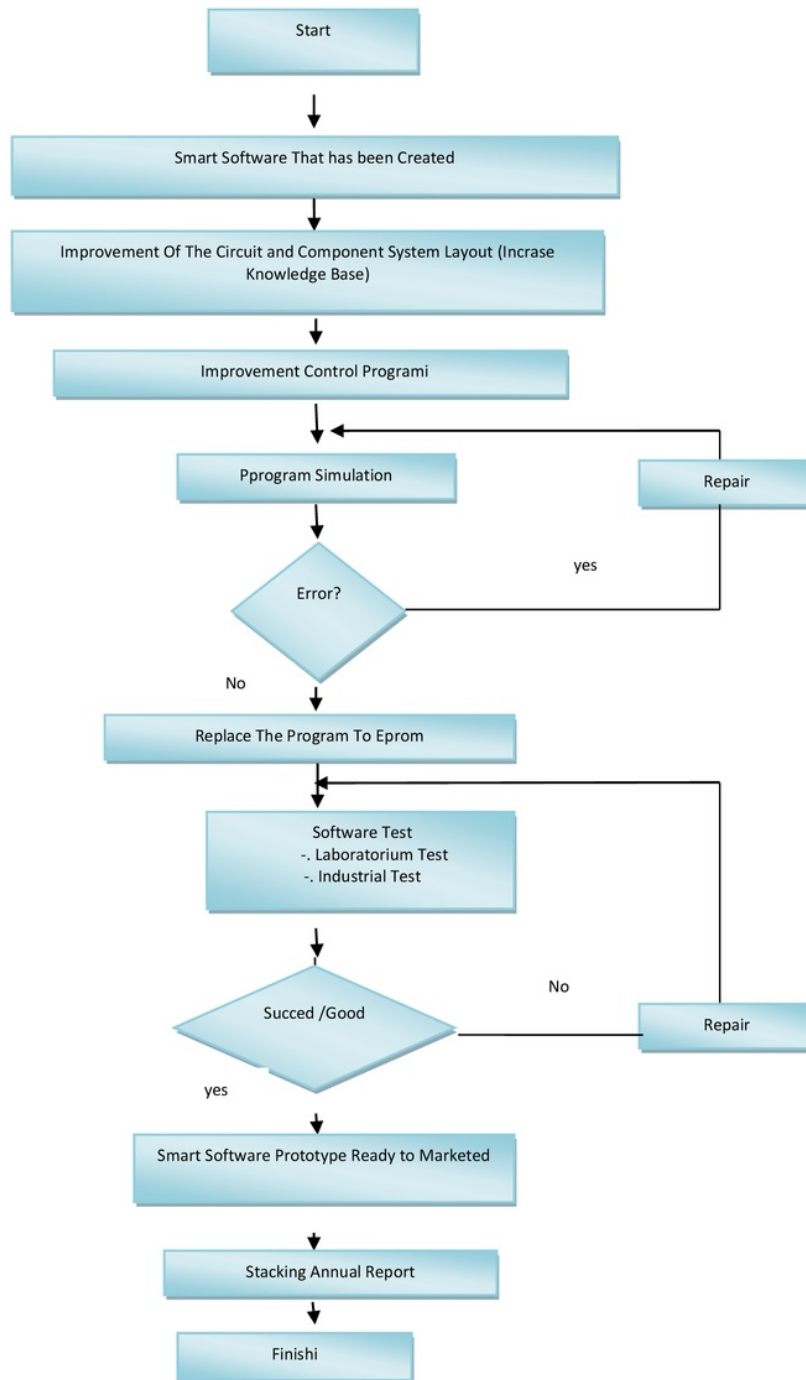
A method of calculating the efficiency accurately and cheaply for a motor for power management was reported by Ibiary, Y. (2003) [5]. Meanwhile Kasim, et al. (2009) [6] in PPI- KIM '2009 reported the results of his research about design and construction of a generator by utilizing permanent magnetic that generates PMG (Permanent Magnetic Generator) with specification 1 Kw 48 V, 18 poles, 300 rpm for demonstrating independence and local capabilities.

Comparison of unbalance voltage factor between phase was discussed by Kim J., K et al. (2005) [7]. Meanwhile, basic knowledge of the electrical machines including an induction motor can be learned a lot from the book of Kothari and Nagrath, II (2004) [8] Lazzarini, MV, and Filho, ER (2007)

[9] reported measurement and control technique of the load torque of a motor without using sensor. The effect of power supply imbalance on 3-phase induction motor performance is discussed by Lee, CY (1999) [10]. Mamat M.M et al. (2006) [11] review condition detector and detection of operation failure of the 3 phase motor using voltage source inverter VSI (Voltage Source Inverter) by utilizing fuzzy logic algorithm in an article reported in the American journal of applied sciences.

Types of induction motors 1 phase are generally used in industries due to having a simple design, feasible operation, compact construction, easy operation, simple maintenance, and low initial capital compared to other types (Pillay et al (2002) [12]. Rijanto. E., and Santoso, A (2009) [13] in an article about design of control system for wind power generator and Sardjono., H. (2008) [14] in his article about thermic voltage converter for national standard each of which will be and has been published in the journal instrumentation. Further applied modeling for the development of motors induction can be found in the article of Soe, NN, et al (2008) [15] as well as in suorsa (2005) [16]. To facilitate the monitoring of disorders causing abnormal operations and improve preventive measures and protection of 3-phase induction motor that plays a major role in the industry, Tjani, Yunusdan Aaron, N (2008) [17] developed a new method using fuzzy logic so that the conventional relay changed into a smart relay.

### Flowchart of the Research



**Figure 6:** Flowchart Research

## RESEARCH METHOD

### Research Location

1. Control Laboratory of Electrical Engineering Department Universitas Negeri Makassar
2. Laboratory of PT.IKI, PT. Semen Tonasa, CV General Electric Workshop & UPTD BPPTSouth Sulawesi Province (Location of Software testing on the Industry).

### Research Instruments (Tools and Materials)

#### 1. Materials:

- a. The components of single-phase induction motor;
- b. A computer set as the tool to design the prototype of application software system using fuzzy diagnosis.

#### 2. Tools:

- a. Tachometer;
- b. Thermometer;
- c. Ammeter;
- d. Voltmeter;
- e. Microphone;
- f. Single-phase Autotransformer;
- g. Three-phase Autotransformer;
- h. A Unit of Computer Set.

### Procedure of Collecting Data

In collecting the data, it applied the following procedures:

1. Interviewing technique with some experts in the field of single-phase induction motor;
2. Referencing technique to support the experimental research which needs some related literature as the comparison between the conceptual theory and its real application;
3. Direct-measurement technique to make clear the achieving goals;
4. Documentation technique to store some indications found after the test is done. This can reinforce in the making of the application of fuzzy diagnosis system method.

### Technique of Data Analysis

To reveal the condition of the components of induction motor (especially the observed single-phase induction motor), it

needs the expert to examine. The examining process includes whole-parts checking with taking apart the components which takes time and high-cost. By using various electrical equipment and mechanism, it shows that the diagnosis process is quite complicated.

By using various electrical equipment and mechanism, then it is not good to hand over this induction motor diagnosis to the non-expert but to those who know exactly about induction motor. If you are not adept in diagnosing, never give a try. Because this electric and mechanism things can be very dangerous for your safety.

### Object Modeling:

Object modeling covers static structure of a system by describing the object of the system, the relation between objects and its attributes, and operating system in each class of the objects[6].

#### a. Class Identification

Class identification of fault diagnostic induction motor system namely the *input* as the parameter (param) and knowledge-based as the manipulation data of the input and output.

#### b. Association Identification

The association confirmed the relation between class and system. *Multiplicity* determines the amount of *instance* of a class which can connect to another single *instance* of the associated class.

Association: parameter – knowledge-based is multiplicity one to many

### Research Findings

After doing software prototype test to the industry sample for about three months, then the software completion is carried as what the industry expect.

The smart software prototype of the induction motor sample in the industry shows positive result as expected from the researcher and the industry.

The pre-test started from motor's components which work in normal by taking pre-data as the comparison to the components' failure. The test is obtained by doing input the five measuring components (temperatures, sound (noise), speed, current, and voltage) at the same time into the computer which equipped with the diagnosis software.

Here below the table contains the values of measurement result which obtained from each industry (in the field).



**Table 1:** The Values of Measurement Result

Suhu	Arus	Kec	Suara	Tegangan	B. Normal	B. Berkarat	B. Kekurangan Gemuk	Bola Hagel Rusak	KU. Normal	KU. Putus	KU. Isolasi Terkupas	KU. Terbakar	KB. Normal	KB. Putus	KB. Isolasi Terkupas	KB. Terbakar	KP. Normal	KP. Meleleh
-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-17-	-17-
42.00	1.00	2,979.00	2.00	256.00	X				X						X			X
40.00	3.20	2,345.00	2.30	250.00	X						X				X			X
37.00	2.70	2,999.00	20.00	230.00		X	X	X			X				X			X
30.00	1.20	2,797.00	30.00	240.00		X	X	X	X				X				X	
30.00	1.20	2,870.00	20.00	240.00		X	X	X	X				X				X	
42.00	1.20	2,979.00	2.00	256.00	X				X						X			X
42.00	1.20	2,979.00	2.00	256.00	X				X						X			X
35.00	0.80	2,900.00	2.00	300.00	X				X				X					X
31.00	1.20	28,790.00	3.00	243.00	X				X					X			X	
42.00	1.20	2,979.00	2.00	256.00	X				X						X			X
75.00	1.00	2,777.00	3.00	260.00	X				X							X		X
37.00	1.50	2,964.00	5.00	200.00	X				X				X				X	
37.00	1.60	2,964.00	5.00	230.00	X				X				X				X	
48.00	1.30	2,751.00	5.00	240.00	X				X				X					X
71.00	1.80	2,772.00	7.00	256.00	X				X						X	X		X
28.00	2.00	2,002.00	3.00	212.00	X						X				X			X
28.00	2.70	2,009.00	3.00	267.00	X						X				X			X
50.00	0.20	2,800.00	5.00	250.00	X						X		X					X
45.00	1.50	2,904.00	3.00	361.00	X						X				X			X
51.00	3.20	2,221.00	18.00	121.00		X	X	X			X				X			X
21.00	3.20	2,892.00	6.00	305.00	X						X				X			X
56.00	3.20	2,797.00	20.00	250.00		X	X	X			X				X			X

#### Diagnosis with Inferencing Technique:

After defining parameter, the next step is diagnosing with inferencing technique. Each of *crisp input* given to the *textfield*, next will be managed by *fuzzy logic* to map the membership.

The test will be done based on the data obtained from the field ( See table 1 and the result in the appendix ).

**If the values of the input as follows (based on the research findings):**

“If the induction motor’s temperature shows 42°C, the speed 2979 rpm, the current 1.0 A, the voltage 256 volts, and the sound (noise) 2dB” then:

The diagnosis result shows that the temperatures of the induction motor is in medium mode, the sound (noise) is very low, the speed is very high, the current is still low, and the voltage is high. It means **the bearing, the running and starting winding are still normal, but the capacitor melts.**

“If the temperatures up to 40°C, the speed 2345 rpm, the current 3.2 A, the voltage 250 volts, and the sound (noise) 2.3 dB” then:

The diagnosis result shows that the temperatures of the induction motor is in medium mode, the sound (noise) is very

low, the speed is low, the current is high, and the voltage is high. It means **the bearing is normal, the running and starting winding have the exfoliated insulation and the capacitor melts.**

“If the temperatures up to 30°C, the speed 2797 rpm, the current 1.2 A, the voltage 240 volts, and the sound (noise) 30 dB” then:

The diagnosis result shows that the temperatures of the induction motor is still low, the sound (noise) is very low, the speed is high, the current is still medium, and the voltage is medium. It means **the bearing is rusty and rubberless, the running and starting winding, and the capacitor are still normal.**

“If the temperatures up to 30°C, the speed 2870 rpm, the current 1.2 A, the voltage 240 volts, and the sound (noise) 20 dB” then:

The diagnosis result shows that the temperatures of the induction motor is still low, the sound (noise) is high, the speed is high, the current is still medium, and the voltage is medium. It means **the bearing is rusty and rubberless, Hagel ball is broken, while the running and starting winding, and the capacitor are still normal.**

The diagnosis result can be seen in Figure. 7

		Sangat Rendah	Rendah	Sedang	Tinggi	Sangat Tinggi
<b>AKIBAT</b>						
Suhu	30	0.0	0.75	0.1818	0.0	0.0
Suara	20	0.0	0.0	0.0	0.625	0.5
Kecepatan	2870	0.0	0.0	0.0	0.516	0.484
Arus	1.2	0.0	0.1666	0.625	0.0	0.0
Tegangan	240	0.0	0.0	0.5	0.3636	0.0

**SEBAB**  
 Suhu 'Rendah', Suara 'Tinggi', Kecepatan 'Tinggi', Arus 'Sedang', Tegangan 'Sedang' diakibatkan oleh 'Bantalan Berkarat, Bantalan Kekurangan Gemuk, Bola Hagel Rusak, Kumparan Utama Normal, Kumparan Bantu Normal, Kapasitor Normal,'

Diagnosa Simpan Reset Keluar

Figure 7: Fuzzy Input by Technic Inferensi

## CONCLUSION AND SUGGESTION

### Conclusions

- Smart software in this research works well as expected from the industry companies (PT. Semen Tonasa, PT. IKI, CV. General Electric Workshop, Lab. of UPTD BPPT South Sulawesi Province, Lab. of Electrical Engineering and Computer Department of Faculty of Engineering UNM) by describing fault diagnosis of single-phase induction motor so it can be handled as fast as could;
- Diagnosis system based on microprocessor succeed to detect damage types of the induction motor against the effects of current, voltage, speed, noise/sound, and unstable temperatures which described by inferencing technique using fuzzy input. The result shows the running winding has insulation exfoliating, machine bearing is still normal, starting winding burns, and the capacitor melts;
- The used parameters as the measurement tools contain of five parameters, where each of it has five *membership function*. It describes that the parameter can detect the faults/damages for about 5<sup>5</sup> or 3125 types of damages/faults.
- Smart software made is flexible which mean it can be expanded to its cause of the faults/damages from the induction motor.

### Suggestions

- To conduct future researches to make **Hardware** which directly can detect the faults/damages in single-phase induction motor against **the effects of current, voltage, and unstable temperatures**;
- To conduct future researches to make **Hardware** which directly can detect multi-faults/damages in single-phase induction motor against **the effects of noise/sound, excessive speed, unstable voltage, unstable electricity current, and unstable temperatures**;
- To conduct future researches to diagnose **three-phase induction motors machine** because its great differences with single-phase machines, from its characteristics or its amounts of **the current, voltage, temperatures, sound/noise, and speed**;

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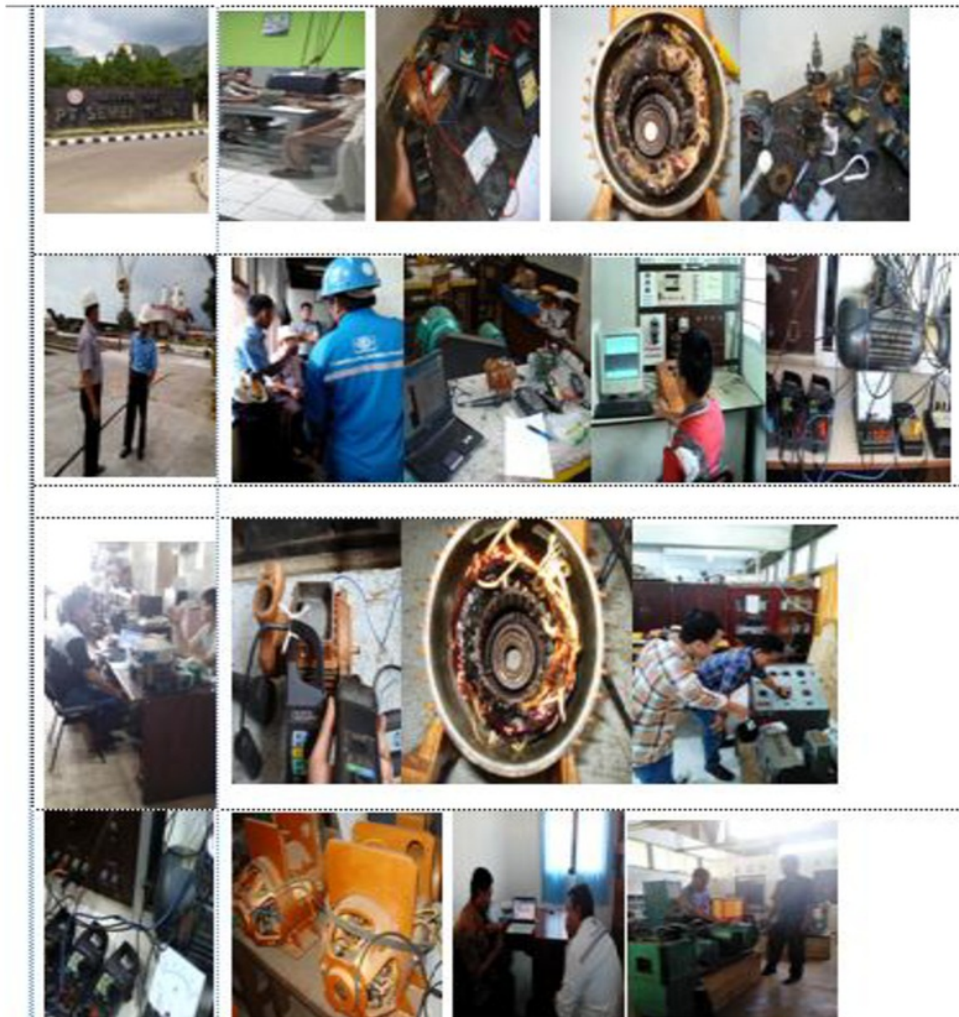
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APPENDIX 1. DATA OF MEASUREMENT RESULTS

Suhu	Arus	Kec	Suara	Tegangan	B. Normal	B. Berkarat	B. Kekurangan GEMUK	BOLA HA-GEL RUSAK	KU. Normal	KU. PUTUS	KU. ISOLASI TERKUPAS	KU. TERBAKAR	KB. Normal	KB. PUTUS	KB. ISOLASI TERKUPAS	KB. TERBAKAR	KP. Normal	KP. MELELEH
-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-17-	-17-
42.00	1.00	2.979.00	2.00	255.00	X				X		X				X			X
40.00	3.20	2.345.00	2.20	250.00	X						X				X			X
37.00	2.70	2.989.00	20.00	220.00		X	X	X			X				X			X
30.00	1.20	2.970.00	20.00	240.00		X	X	X	X				X				X	
42.00	1.20	2.979.00	2.00	255.00	X				X						X			X
42.00	1.20	2.979.00	2.00	255.00	X				X						X			X
35.00	0.80	2.900.00	2.00	300.00	X				X				X					X
31.00	1.20	23.710.0	3.00	243.00	X				X					X				X
42.00	1.20	2.979.00	2.00	255.00	X				X						X			X
75.00	1.00	2.777.00	3.00	260.00	X				X							X		X
37.00	1.50	2.964.00	5.00	200.00	X				X				X				X	
37.00	1.60	2.964.00	5.00	220.00	X				X				X				X	
48.00	1.30	2.751.00	5.00	240.00	X				X				X					X
71.00	1.80	2.772.00	7.00	255.00	X				X						X			X
28.00	2.00	2.002.00	3.00	212.00	X						X				X			X
28.00	2.70	2.003.00	3.00	267.00	X						X				X			X
50.00	0.20	2.900.00	5.00	250.00	X						X				X			X
45.00	1.50	2.984.00	3.00	351.00	X						X				X			X
51.00	3.20	2.221.00	18.00	121.00		X	X	X			X				X			X
21.00	3.20	2.992.00	6.00	305.00	X						X				X			X
56.00	3.20	2.797.00	20.00	250.00		X	X	X			X				X			X
23.00	0.00	2.450.00	14.00	170.00	X				X								X	
40.00	1.70	2.500.00	7.00	220.00	X				X				X				X	
40.00	0.50	2.500.00	12.00	170.00	X				X				X				X	
25.00	2.80	2.750.00	18.00	161.00		X	X	X			X				X			X
45.00	3.20	2.987.00	40.00	250.00		X	X	X			X				X			X
27.00	2.00	2.199.00	20.00	250.00	X	X	X	X			X				X			X
40.00	1.20	2.911.00	20.00	220.00		X	X	X	X				X				X	



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